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Review

Estimating Economic and Livelihood Values of the World's Largest Mangrove Forest (Sundarbans): A Meta-Analysis

Akbar Hossain Kanan , Mauro Masiero * and Francesco Pirotti

Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padova, 35020 Legnaro, Italy; kanan.sust@gmail.com (A.H.K.); francesco.pirotti@unipd.it (F.P.)

* Correspondence: mauro.masiero@unipd.it; Tel.: +39-049-827-206

Abstract: We explored the state of the art economic and livelihood valuation of ecosystem services (ES) in the Sundarbans mangroves, including a comparative analysis between the Bangladesh and Indian parts of the region. We identified 145 values from 26 studies to estimate the Sundarbans' economic and livelihood values. The number of ES valuation studies of the Sundarbans is scant, and it has gradually increased over time, focusing mainly on the estimation of provisioning ES (66.2%), followed by regulating and maintenance (25.5%), and cultural (8.3%) ES. However, recently, attention has been paid to estimation, regulating and maintenance, and cultural ES. The number of studies on ES was higher for the Bangladesh (73%) part of the Sundarbans than the Indian (27%) one. The estimated economic values of the Sundarbans' provisioning, regulating and maintenance, and cultural ES were US \$ 713.30 ha^{-1} yr^{-1}, US \$ 2584.46 ha^{-1} yr^{-1}, and US \$ 151.88 ha^{-1} yr^{-1}, respectively. Except for cultural ES, the identified values for the other two ES categories were about 1.5 to 2.5 times higher for the Bangladesh Sundarbans compared to the Indian ones. The results of the meta-regression model showed that the estimated economic and livelihood values of ES are affected by the associated variables (e.g., type of ES, valuation methods, study area, population, and GDP). Our study also identified some remarkable gaps and limitations in the economic and livelihood valuation of the ES of the Sundarbans, highlighting the need for further research to find out the values of all ES to help with policy decision-making.

Keywords: mangrove; ecosystem services; economic valuation; livelihood; Bangladesh; India

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1. Introduction

Mangrove forests are found along coastlines in the tropics and subtropics of the world [1,2]. The total estimated area of global mangroves ranges from 110,000 to 240,000 km^2, and the largest extent of mangroves is found in Asia (42%), followed by Africa (20%), North and Central America (15%), Oceania (12%), and South America (11%) [3]. Mangrove forests in South Asia occur on the tidal sea edge of Bangladesh, India, Pakistan, and Sri Lanka, where they represent about 7% of global mangrove forests [4]. The Sundarbans is the largest contiguous mangrove forest in the world: it covers 3% of the global mangrove forest area [5,6] spanning 10,000 km^2, of which 62% (6200 km^2) is placed in Bangladesh and the remaining 38% (3800 km^2) in India [7]. Despite being separately managed since the partition of India in 1947, the Sundarbans constitute a continuum in ecological terms as well as with reference to the socio-economic context [8]. Recognizing the importance and uniqueness of the Sundarbans ecosystem, the Sundarbans National Park (SNP) in India and the Sundarbans Reserve Forest (SRF) in Bangladesh have been declared World Heritage Sites by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in 1987 and 1997 respectively. SRF has also been included as a Ramsar site in 1992 [7,9,10].

The Sundarbans mangrove forest is a hotspot for a wide range of ecosystem services (ES) [2]. According to the Millennium Ecosystem Assessment (MEA), ES represent the multiple benefits ecosystems provide to humans. The forest ES includes all the goods and services a forest ecosystem offers. Building on the ES classification framework of MEA (2005), the Common International Classification for Ecosystem Services (CICES) classified the ES into three categories: (i) Provisioning; (ii) Regulatiing and maintenance; (iii) Cultural [11]. Despite growing global attention to ES assessment and valuation [12], existing studies focused on the Sundarbans are patchy, and there is a research gap in the systematic assessment of ES provided by this mangrove forest. Therefore, their economic value remains largely unknown and underestimated [13]. The Sundarbans act as a natural safeguard for coastal communities against storms, cyclones, and coastal soil erosion. They deliver many materials and resources that support daily life for local communities and households [14,15]. In addition to this, they provide a habitat for wild fauna and flora, which is important for maintaining coastal biodiversity and ecological integrity [16]. This includes hosting many threatened and endangered species such as the Royal Bengal tiger, estuarine crocodile, Indian python, and some species of river dolphins [8]. Consequently, the Sundarbans is considered a haven for biodiversity conservation and, at the same time, an important hub for the provision of ES [17]. About 3.5 million Bangladeshi and 4 million Indian people are directly or indirectly dependent on these ES for their livelihood and socio-economic wellbeing [8,18–20]. However, the Sundarbans are decreasing quickly, with an annual rate of 1.2% [20], which is higher than the global rate of 0.15% [2], due to anthropogenic and climate change reasons [21–23]. Das and Datta [24] reported that anthropogenic activities are one of the major causes for ecological degradation of the Sundarbans. For instance, given the increasing population density in the Sundarbans Biosphere Reserve (SBR) (The SBR in West Bengal, India, is part of the largest mangrove forest ecosystem in the world. It covers an area of 9630 km^2 and is divided into the core, buffer, and transition zones (Figure 1). The core zone does not allow any anthropogenic activities (except research) to conserve the major habitats of flora and fauna of the Sundarbans. The core and buffer zone covers 4263 km^2, and the 2585 km^2 Sundarbans Tiger Reserve (STR) is located inside the core zone. The buffer zone is used for fishing and collecting honey with permits. The transition zone covers an area of 5367 km^2, a densely settled area used for agricultural practices [25]) and the decreasing one within the Sundarbans Impact Zone (SIZ) (The SIZ is an area within a 20 km wide radius surrounding the periphery of the Bangladesh Sundarbans. About 1750 km^2 area (10 km wide from the forest boundary) inside the SIZ was declared as an Ecologically Critical Area (ECA) to protect biodiversity from anthropogenic impact (Figure 1). The SIZ also comprises five districts (Bagerhat, Khulna, Satkhira, Pirojpur, and Barguna), and the population residing within this area are directly dependent on the Sundarbans for their livelihood [26]). The number of people depending on the Sundarbans ES is increasing, which may lead to a growing demand for resources [7], a growing risk of over exploitation [13], and ultimately the integrity of mangrove forest ecosystems [27].

Despite the emergence of the ES concept in the last decades, benefits provided by natural ecosystems are often poorly recognized and understood, and one of the reasons behind this is the failure to capture their full economic value [28]. For instance, many policy makers and resource managers in Bangladesh, as well as in other countries, often view ES as having no significant value [29]. Moreover, many are not aware of the relevance of ES and their effects on human life [30]. ES economic valuation plays a key role in understanding their importance as it makes hidden values visible [31]. Most importantly, the economic valuation and analysis help in the decision-making for sustainable resource management and allocation, thus providing useful inputs for driving development processes and strategies [13,30,32–34]. For example, economic analysis can help identify allowable amounts of goods that can be extracted by resource users based not only on bio-physical and ecological balance but also on the analysis of trade-offs with other services.

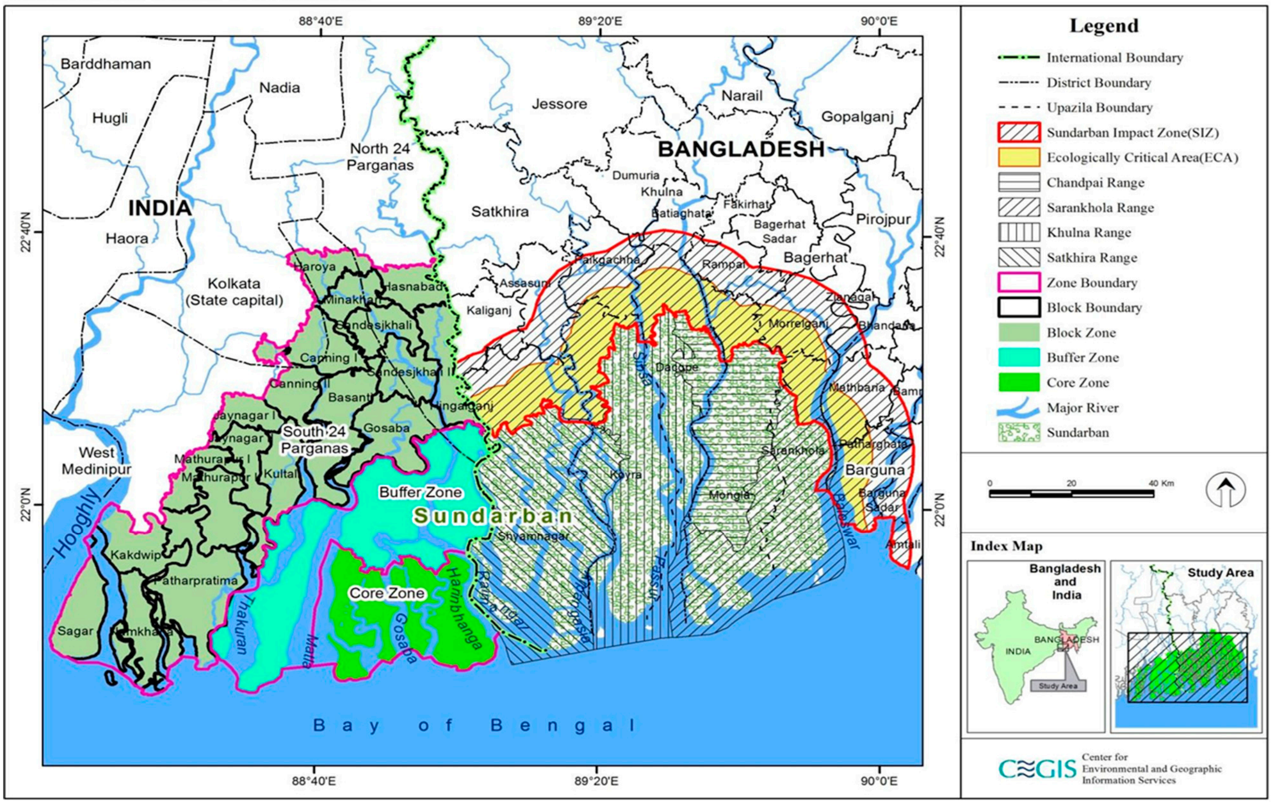

Figure 1. Legal boundary and management unit of Sundarbans [26].

Research on ES delivered from the Sundarbans and their valuation has increased in recent years. However, most of the studies consist of policy documents, while the scientific literature on economic valuation is still very limited and the information is scattered [30,35]. Despite the growing attention on the economic valuation of the ES from the Sundarbans, there are some limitations regarding their identification, classification, and valuation [13]. Many studies cover only a few ES items to estimate the Sundarbans' economic and livelihood values and just focus either on the Indian or Bangladeshi part of the region, but there is not a systematic assessment of a broad range of ES for the whole Sundarbans.

In our study, we try to fill this knowledge gap and, by exploring the existing state of the art on the economic valuation of ES in the Sundarbans, cover both the Bangladesh and Indian Sundarbans to provide an economic valuation of the entire region. To the best of our knowledge, this is the first attempt to study with such a scope and aim.

To achieve this, we have addressed the following specific objectives: (1) Searching and analyzing existing economic valuation studies on the Sundarbans by highlighting their key features (e.g., publication year, number and type of ES studied, and methodologies used) and identifying valuation gaps; (2) Summarizing results in order to compile estimates of economic values of (key) ES delivered by the Sundarbans; (3) Providing estimates of livelihood values of ES within the same area; (4) Understanding the effects of explanatory variables (e.g., valuation methods, ES types, study area, GDP, and population density) on estimated economic and livelihood values. For each objective, a comparative analysis between the Bangladesh and Indian Sundarbans has been performed even though the ecological characteristics are the same and the forest management practices are still distinct.

2. Background of the Study Site

This section provides background information about the study site regarding socio-ecological aspects (Section 2.1) and the management system (Section 2.2).

2.1. Socio-Ecological Aspects

The Sundarbans are formed in the estuary created by the Ganges, Brahmaputra, and Meghna rivers in the Bay of Bengal. Geographically, they are located within 21°32′ to 22°40′ N and 88°05′ to 89°51′ E (Figure 1). About 30% of the Sundarbans are covered by water and shaped by rivers, canals, and tidal flows [26]. The salinity level in the Bangladesh Sundarbans is lower compared to the Indian parts due to more upstream freshwater flow [20,26]. However, the other environmental conditions and geographical settings are almost similar. The forest is inundated twice a day by the tide [36] and is characterized by a tropical climate with dry and monsoon seasons. During the monsoon, tropical cyclones and smaller tidal events regularly hit the Sundarbans, causing severe flooding and wind damage [7].

The Sundarbans support a wide variety of aquatic and terrestrial flora and fauna species. A total of 334 plant species, 165 algal, 13 orchids, 17 ferns, 87 monocotyledons, 230 dicotyledons, including 35 legumes, 29 grasses, 19 sedges, and 18 euphorbias, are recorded in the Sundarbans areas [37,38]. There are nearly 392 animal species in the Sundarbans, which includes 35 reptiles, 315 birds, and 42 mammals. The Sundarbans also provide habitat for 291 fish species [39], 26 crab species, 20 shrimp species, and 8 lobster species, many of which are endangered. The density of flora and fauna is greater in the Bangladesh Sundarbans compared to the Indian parts, which provides higher ES values for the Bangladesh Sundarbans. For instance, valuable plant species, namely Sundori (*Heritiera fomes*) and Golpata (*Nypa fruticans*), grow more in the Bangladesh Sundarbans than in the Indian ones [26]. Moreover, *Heritiera fomes*-dominated forests store a greater amount of ecosystem carbon compared to other vegetation compositions [10]. This biodiverse ecosystem provides support and resources for millions of Bangladeshi and Indian people. Nishat et al. [26] reported that about 2.30 million people (560 people/km^2) lived in the SIZ of Bangladesh in 2011, with an annual 0.13% population decrease recorded since 2001 due to the migration caused by low income and adverse environmental conditions. About 4.42 million people (1090 people/km^2) lived within the Indian SBR in 2011, showing a 1.78% per year increase since 2001. The average per capita income per year of SIZ and SBR is about US $ 330 and US $ 185, respectively, and the contribution of these areas to the local and national economies is significant, though valuations are just limited to marketed ES (i.e., provisioning ones). For example, the Bangladesh Sundarbans cover more than 50% of the national forest area and account for nearly 41% of the country's total forest revenues [26].

The Sundarbans mangrove forests in Bangladesh and India are declining quickly: Giri et al. [20] reported that the Sundarbans mangrove forest area decreased by 1.2% from 1970 to 2000. Such a decline is due to both anthropogenic—e.g., over-exploitation of resources, agricultural expansion, industrialization, etc.—and natural factors—e.g., cyclonic storms, sea level, salinity rise, etc. [23]. For example, Bangladesh and Indian governments recently made an agreement to build a coal-fed thermal power plant in Rampal, 14 km north of the Sundarbans [40]. Many environmental activists reported that the proposed location of the Rampal Power Station would violate provisions of the Ramsar Convention and UNESCO rules for World Heritage Site, threatening the biodiversity and ecological values of the Sundarbans [26]. Moreover, the salinity level of the Sundarbans is increasing due to dam constructions and associated changes in the freshwater flows. Islam and Gnauck (2008) reported that the freshwater discharge of the Ganges River was reduced from 3700 m^3/s in 1962 to 364 m^3/s in 2006 due to the construction of the Farakka Barrage in 1975. The Sundarbans mangroves are also extremely vulnerable to climate change impacts. For instance, the reported sea level rise adjacent to the Sundarbans is +3.90 $\pm$ 0.46 mm/year [26]: it has been estimated that 40%–60% of the mangrove area will decrease if sea level rise grows up to 1 m [10]. Moreover, the occurrence of cyclonic storms increased by 26% from 1881 to 2001 in the Sundarbans coastal area [37]. Consequently, in the coastal ecosystems, the livelihood security of the local people depending on them as well as the local and national economy are under threat [20,41], which could affect the effectiveness of development policies and efforts promoted by national governments and international bodies and would finally result in failing to achieve some of United Nations Sustainable Development Goals.

2.2. Management System

The Sundarbans are managed separately by Bangladesh and India, but they were considered a single entity until the partition of India in 1947 [8]. In the mid-1800s, the Sundarbans was declared a reserve forest by the colonial administrator for the sake of resource exploitation. However, after gaining independence from British colonial rule (1947), India established three wildlife sanctuaries that were later merged into a national park. After that, for better conservation, the Indian Sundarbans were divided into three parts, namely core, buffer, and block zone (non-forest areas and reclaimed areas) (Figure 1). The administrative zone of the Indian Sundarbans is located in the 24 Parganas district of West Bengal [7]. From 1947 to 1971 (Pakistan period), the Bangladesh Sundarbans were managed for commercial purposes with large volumes of tree felling for industrial raw materials. After the independence from Pakistan (1971), the government of Bangladesh imposed to stop tree felling. However, non-timber forest products (NTFPs) are still harvested based on seasonal licenses issued by the Forest Department (FD). In 1977, the Bangladesh Sundarbans were divided into three wildlife sanctuaries, namely Sundarbans east, west, and south, under the Wildlife Act 1974 [42]. To ensure better protection of the Sundarbans and their wildlife, a 10 km buffer area around the forest was declared an Ecologically Critical Area (ECA) under the Bangladesh Environment Protection Act 1995 in 1999. Accordingly, the SIZ was also created to protect biodiversity; it includes lands up to 20 km from the forest boundary line. At present, the wildlife of the whole Sundarbans is protected under the Bangladesh Wildlife Act 2012, according to which wildlife should not be killed or captured [26]. Today, the Sundarbans area of Bangladesh is divided into four administrative units, i.e., Sharankhula, Chandpai, Khulna, and Sathkhira ranges [7].

Although the management policies of Bangladesh and India have their own priorities and specificities, in 2011, the two countries agreed and signed a bilateral cooperation agreement on the conservation of the Sundarbans. This includes, in particular, commitments to sharing relevant information and technical knowledge, developing joint research and monitoring, and tackling poaching and illegal wildlife trade [26]. However, some controversial issues have been observed in the last few years. For instance, the government of Bangladesh imposed a seasonal ban on the catching, sale, and transportation of hilsa (*Tenualosa ilisha*) in Bangladesh from 1st October to 22nd October (every year) to save mother hilsa during the breeding and thus increase national hilsa output. However, Indian fishermen often encroach into Bangladesh's fishing zone during the peak season of hilsha catching, and they take advantage of the absence of Bangladeshi fishermen during the period of ban on fishing [26].

3. Material and Methods

3.1. Literature Identification and Screening

Literature on the economic valuation of ES and livelihood values of Sundarbans is scanty and includes both scientific publications and grey literature, in particular policy documents. Therefore, for the aims of our literature review, we considered both scientific databases—namely Scopus, Science Direct, CABI Direct, CABI Forest Science Database, and Google Scholar—and key policy documents to identify relevant literature and references for this study. We searched for literature published until the end of 2023. The searching and screening procedure adopted for the literature review is described in detail in Appendix A. A total of 26 relevant publications/documents reporting estimated economic and livelihood values for ES delivered by the Bangladesh and Indian Sundarbans were found from the abovementioned sources and considered for the aims of the research.

3.2. Database Preparation

A database reporting all selected studies was built to collect economic and livelihood values for ES. The database was designed to take into account approaches and methodological aspects already adopted [30]. This included, among others, the distinction between flow and stock benefits, as well as the valuation of both economic and livelihood values. In this paper, we considered only ES flow (e.g., increment of timber production and carbon sequestration) and not ES stock (e.g., timber total growing stock and carbon storage) to identify the economic values of ES. Flow values measure ES values at two points over time (e.g., over one year), whereas stock benefit measures ES values at a single point in time. Consequently, flow benefits are measurable and comparable on a temporal (e.g., annual) basis. Our study also distinguished monetary values into economic and (forest-based) livelihood values. The economic value measures the benefit—in terms of increased human welfare—derived from a certain good or service in monetary terms. Forest-based livelihood values are the income equivalent of the amount of gathered and marketed provisioning ES [43,44]. Therefore, in this study, collectors' income from collected and marketed provisioning ES is considered a livelihood value for the Sundarbans. A total of 127 ES values were found for both Bangladesh and Indian Sundarbans. In some cases, the existing literature made ES values available just for one country (i.e., either Bangladesh or India): missing values—for a total of 18 ES values—12 economic and 6 livelihood values—were estimated via an expert-based benefit transfer [33]. This type of valuation is applicable to similar studies and policy sites [12]. In this regard, two expert groups (e.g., academic, governmental, and non-governmental research staff), one from Bangladesh and one from India, assessed the missing values based on relative values that are already found for one country and provided inputs to fill existing valuation gaps. Finally, we considered a total of 145 ES values—both economic and livelihood ones—for the database (Figure 2). For each value, key features were identified and recorded with regard to publication characteristics (e.g., data source and study year), ES categories (e.g., provisioning, regulating, maintenance, and cultural), ES valuation methods (e.g., market price, travel cost, benefit transfer, contingent valuation method, etc.) and site characteristics (e.g., study area boundaries, GDP, and population density). We cross-checked the information regarding GDP and population density vis-a-vis World Bank data [45]. A summary of key literature review results is presented in detail in Appendix B.

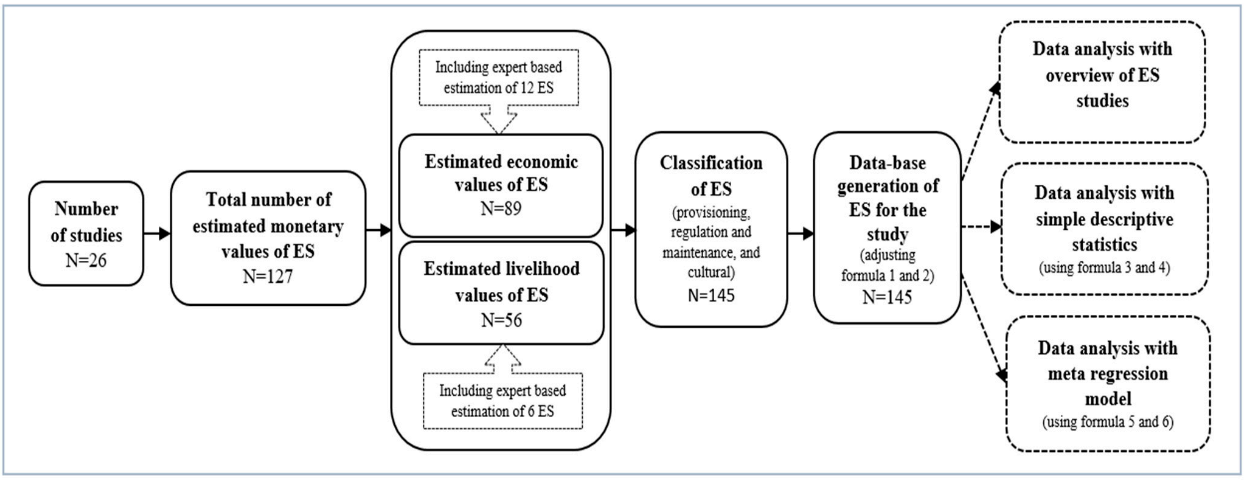

Figure 2. Systematic review for database preparation and analysis.

In this study, we distinguished ES according to the Common International Classification for Ecosystem Services (CICES) version V5.1 [11], which classifies ES according to 3 categories (i.e., provisioning, regulating and maintenance, and cultural) and 10 divisions. The latter are further divided into groups and then classes. CICES was preferred to other existing classification frameworks (e.g., the one by the Millennium Ecosystem Assessment) as it simplifies the identification, recording, and comparative analysis of ES and their values [30]. A detailed overview of the classification of Sundarbans ES is provided in Appendix C.

The ES identified via the literature review were valued in different years and expressed in several currencies (e.g., United States Dollar, Euro, Bangladeshi Taka, and Indian Rupee). Moreover, some studies estimated the total value of ES per year for a whole forest area (value yr^{-1}) or part of a forest, while some others provided values per hectare and per year (value ha^{-1} yr^{-1}). In order to express economic values in a consistent manner, they were translated into the same monetary metrics for a certain year [30]. We transformed all values into values per hectare and year and converted them in 2019 constant US $ (US $ ha^{-1} yr^{-1}) by adjusting the inflation rate. Total annual economic values were converted into unit values (i.e., per ha) by dividing them by the total forest area to which studies referred. We also calculated livelihood values of ES based on the collector income per year (US $ $collector^{-1}$ yr^{-1}) from forest-based ES. For calculating economic and livelihood values, the year of publication was considered as a base year unless publications specifically mentioned the year of estimation. The estimated ES values were finally expressed in 2019 constant US $.

The whole procedure followed using the Equations (1) and (2) for estimating and adjusting economic values:

$$\begin{gathered}\text{If, } i < 2019 \\ EV_{2019} = EV_i\{(1 + IR_{i+1})(1 + IR_{i+2})(1 + IR_{i+3})\cdots\cdots\cdots.(1 + IR_{i+n})\}\end{gathered} \tag{1}$$

$$\begin{gathered}\text{If, } i > 2019 \\ EV_{2019} = EV_i\{(1 + IR_{i-1})(1 + IR_{i-2})(1 + IR_{i-3})\cdots\cdots\cdots.(1 + IR_{i-n})\}^{-1}\end{gathered} \tag{2}$$

$V_i = \frac{Tv_i}{A}$ [when the total value for a single ES over the entire forest area available in US $]; $Tv_i = \frac{Tv_{i(dc)}}{ER}$ [when the total value for a single ES over the entire forest area is not available in US $].

The whole procedure followed using the Equations (3) and (4) for estimating and adjusting livelihood values:

$$\begin{gathered}\text{If, } i < 2019 \\ LV_{2019} = LV_i\{(1 + IR_{i+1})(1 + IR_{i+2})(1 + IR_{i+3})\cdots\cdots\cdots.(1 + IR_{i+n})\}\end{gathered} \tag{3}$$

$$\begin{gathered}\text{If, } i > 2019 \\ LV_{2019} = LV_i\{(1 + IR_{i-1})(1 + IR_{i-2})(1 + IR_{i-3})\cdots\cdots\cdots.(1 + IR_{i-n})\}^{-1}\end{gathered} \tag{4}$$

where

i = Reporting year of ES values (year of estimation or publication),
EV_i = Economic value of the reporting year,
LV_i = Livelihood value of the reporting year,
Tv_i = Total value for a single ES for the entire forest area in US $,
A = Forest area in ha,
$Tv_{i\,(dc)}$ = Total value for a single ES of the entire forest area in different currency than US $,
ER = Exchange rate between US $ and a different currency,
IR = Inflation rate of US $,
n = Number of years to 2019.

3.3. Data Analysis

First, we investigated the current state of knowledge on the economic and livelihood valuation of ES through descriptive analysis. We analyzed the trend of studies, types of ES values, and classification of ES. For these key features, a comparative assessment was performed between Bangladesh and Indian Sundarbans to understand the status of ES studies independently.

Second, we calculated the economic and livelihood values of ES for Bangladesh and Indian Sundarbans separately. Simple descriptive statistics (range, mean, and standard deviation) were used to compare the estimated ES values for Bangladesh and Indian Sundarbans. Then, we estimated economic (US \$ ha^{-1} yr^{-1}) and livelihood (US \$ $collector^{-1}$ yr^{-1}) values of ES for the entire Sundarbans, according to Formulas (5) and (6), respectively:

$$\text{Economic value of the Sundarbans ES}\left(\text{US \$ ha}^{-1}\text{yr}^{-1}\right) = \frac{(V_B \cdot A_B) + (V_I \cdot A_I)}{A_S} \quad (5)$$

$$\text{Livelihood value of the Sundarbans ES}\left(\text{US \$ collector}^{-1}\text{yr}^{-1}\right) = \frac{(V_B + V_I)}{2} \quad (6)$$

where

V_B = ES value of Bangladesh Sundarbans,
V_I = ES value of Indian Sundarbans,
A_B = Total area of Bangladesh Sundarbans,
A_I = Total area of Indian Sundarbans,
A_S = Total area of Sundarbans.

Finally, we conducted a meta-regression analysis of the selected primary studies to investigate possible reasons behind the variations found in the estimates [46]. Based on our database, we defined the following four types of explanatory variables to be used as inputs for the meta-regression model: (1) ES categories (i.e., provisioning, regulating and maintenance, and cultural); (2) ES valuation methods (e.g., market price, travel cost, benefit transfer, and contingent valuation method); (3) Study area (i.e., Bangladesh or Indian Sundarbans); (4) Socio-economic characteristics (i.e., GDP and population density). GDP has already been used as an explanatory variable within existing literature on ES value [47,48]. As regards population density, there is evidence that the increase in population density combined with the development of technology tends to intensify the use of ecosystems (e.g., to acquire economic profits). At the same time, a higher population density tends to be linked to land reclamation and other human activities that significantly change the structure of ecosystems and may affect the maintenance of many ecosystem services [49]. The study site has also been considered an explanatory variable within the existing literature on ES valuation [47]. In our study, the ecological conditions of the study site (Bangladesh and Indian Sundarbans) are the same, but the area and administration of the study site are different; thus, there might be a variation in delivered ES and values. For this reason, we used the study site as an explanatory variable. These explanatory variables were incorporated with our estimated economic and livelihood values of ES (dependent variable). The dependent variable in our meta-regression model was a vector of ES values standardized to 2019 US \$ ha^{-1} yr^{-1} for economic and US \$ $collector^{-1}$ yr^{-1} for livelihood values. In the case of livelihood values, no variations were found according to the type of ES and valuation method; therefore, study area and socio-economic characteristics were considered as explanatory variables. A list of dependent and independent variables, their definition, description, and omitted variables used for the meta-regression model is presented in detail in Table 1.

In our meta-regression model, we investigated the single and joint effects of explanatory variables using three different models (Model 1, Model 2, and Model 3), considering the effects of single variables, all variables, and two variables, respectively. In the case of two variables, we considered the following: (i) ES types and (ii) valuation methods to find out the effect on estimated economic values, and (i) GDP and (ii) population density for livelihood values. By running three separate models, we aimed to gain a more in-depth understanding of the variables influencing the economic value of ES [47]. The Equations (7) and (8) describe the two models with reference to the economic and livelihood value of ES, respectively:

$$\text{Economic value of ES: } \ln(y_i) = a + b_a X_{et} + b_b X_{vt} + b_c X_{sa} + b_d X_{se} + u_i \quad (7)$$

$$\text{Livelihood value of ES}: \ln(y_i) = a + b_c X_{sa} + b_d X_{se} + u_i \quad (8)$$

where

ln (y) = Dependent variable,
i = Assumes values from 1 to 145 (number of observations of ES),
a = Constant,
b_a, b_b, b_c and b_d = Coefficients of associated variables,
X_{et} = Type of ES,
X_{vt} = Types of ES valuation method,
X_{sa} = Study area,
X_{se} = Socio-economic characteristics,
u_i = Vector of residuals.

Table 1. Used variables and their definition, description, and omitted variables of the meta-regression model.

	Variables	Definition and Description of Variables	Omitted Variables of the Meta-Regression Model
Dependent variable	$\ln(y_i)$	The dependent variable in the meta-regression model was a vector of ES values standardized to 2019 US \$ ha^{-1} yr^{-1} for economic and US \$ $collector^{-1}$ yr^{-1} for livelihood values.	(Not applicable)
Types of ES	1. Provisioning 2. Regulating and maintenance 3. Cultural	According to CICES, three types of ES were recorded from the selected primary studies.	Provisioning
Valuation method	1. Market price 2. Travel cost 3. Value transfer 4. Willingness to pay	Four types of valuation methods for different ES were recorded from the selected primary studies.	Market price
Study area	1. Area 6000 km^2 (Bangladesh Sundarbans) 2. Area 4000 km^2 (Indian Sundarbans)	Ecologically, the study areas are the same. However, based on the scale, the study areas were divided into two categories: 6000 km^2 (Bangladesh Sundarbans) and 4000 km^2 (Indian Sundarbans).	Bangladesh Sundarbans (6000 km^2)
Socio-economic	1. GDP/capita > US \$ 1500 2. GDP/capita < US \$ 1500 1. Population density/km^2 > 1000 2. Population density/km^2 < 1000	World Bank report was considered to record GDP/capita and population density/km^2 for each primary study. The GDP values were divided into two categories, i.e., high (GDP/capita > US \$ 1500) and low (GDP/capita < US \$ 1500). The population density was also divided into two categories, i.e., high (Population density/km^2 > 1000) and low (Population density/km^2 < 1000).	GDP/capita > US \$ 1500 Population density/km^2 > 1000

4. Results

4.1. Overview of Ecosystem Services Studies for Sundarbans

A total of 145 estimated ES values were identified and analyzed to estimate the monetary values of ES provided by the Sundarbans. Of these, 127 were selected from 26 publications, and the remaining 18 were derived through an expert-based estimation. The number of studies and publications on ES from the Sundarbans increased gradually from 1995 to 2023, and no studies were found for the years 2012, 2022, and 2023 (Figure 3). According to our review, the first study on the economic valuation of the Bangladesh Sundarbans was published in 1995, while the first study for the Indian Sundarbans was published in 2009 (Appendix B). Early publications were mainly focused on the estimation and assessment of provisioning ES, while the attention paid to regulating and maintenance, as well as to cultural ES, is more recent (Figure 3).

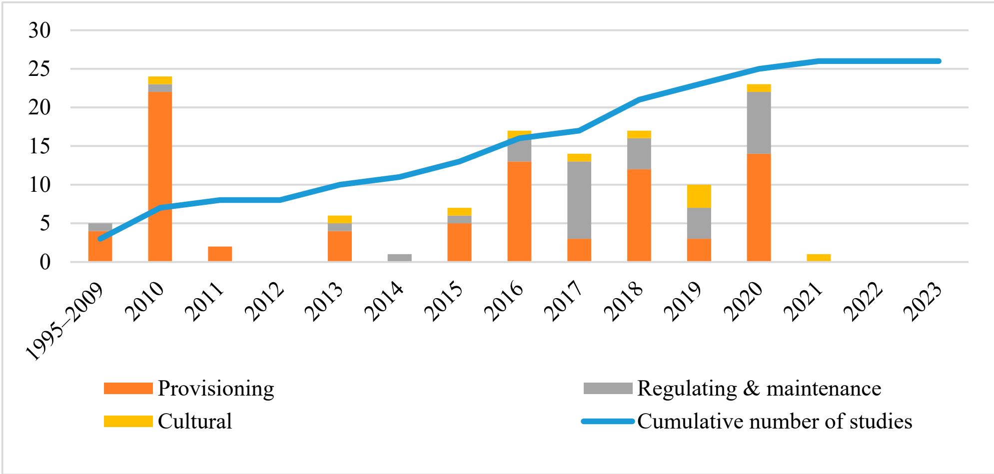

Figure 3. Number of studies and valued ES.

The literature review also revealed that most of the studies identified refer to the Bangladesh Sundarbans (73%), with a lower proportion (27%) referring to the Indian Sundarbans. The estimation of economic values (61.4%) prevails on those for livelihood values (38.6%) of ES. We found that most of the estimated ES values regard provisioning ES (66.2%), followed by regulating and maintenance (25.5%) and cultural (8.3%) ES. According to the review, studies targeting the Bangladesh Sundarbans prevail over those scoping the Indian Sundarbans (73% vs. 27%) (Figure 4).

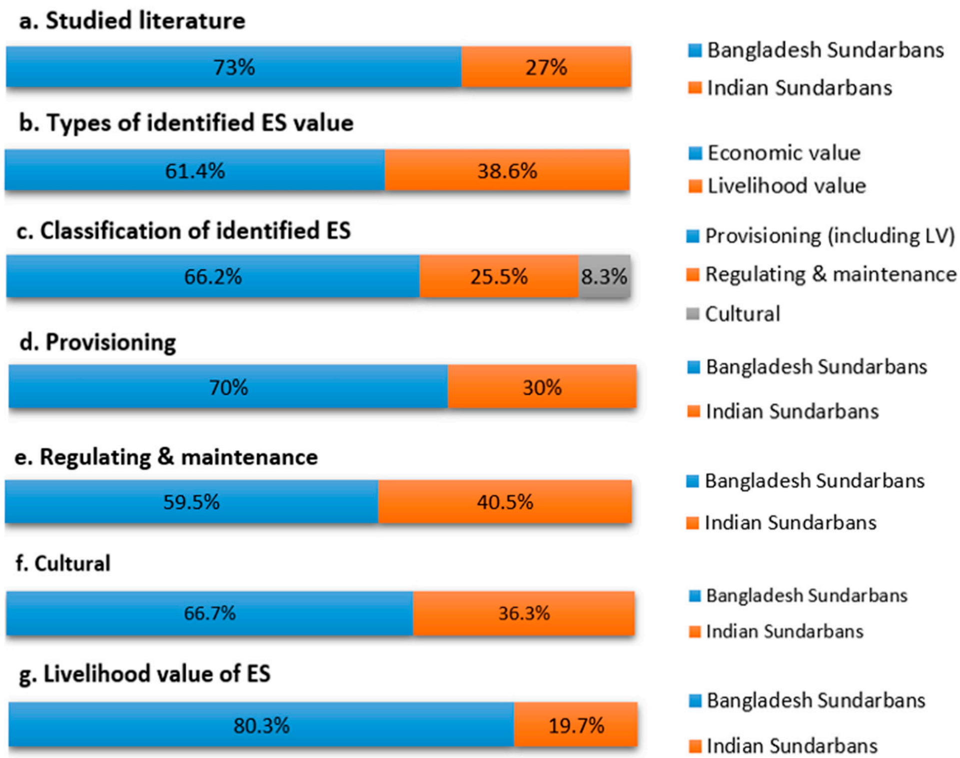

Figure 4. Percentage incidence of key-features for ES estimations gathered from existing literature and studies.

4.2. Economic Values of Sundarbans Ecosystem Services

We estimated the economic values for 25 ES (i.e., 12 provisioning, 11 regulating and maintenance, and two cultural ES) and the livelihood values for 10 ES. The estimated economic values of the Bangladesh and Indian Sundarbans were described with reference to the number of observations as well as the range, mean, and standard deviation (±SD) relative to every ES. We also computed total values for provisioning, regulating and maintenance, as well as cultural ES (Table 2) and average livelihood values of ES (Table 3), both separately for the Bangladesh and Indian Sundarbans and for the whole Sundarbans.

Table 2. Estimated economic values of Sundarbans ES (US $ ha^{-1} yr^{-1}).

ES	Bangladesh Sundarbans		Indian Sundarbans		Entire Sundarbans
	No. Observation (Range)	Mean (±SD)	No. Observation (Range)	Mean (±SD)	
Provisioning					
Fish	4 (76.40–1052.76)	418.92 (445.94)	2 (102.77–113.21)	107.99 (7.38)	295.08
Shrimp	1 (na)	110.00 (na)	1 (na)	35.00 (na)	80.12
Shrimp fry	1 (na)	78.33 (na)	1 (na)	26.67 (na)	57.75
Crab	1 (na)	106.38 (na)	2 (1.17–97.24)	49.21 (67.93)	83.61
Honey	2 (30.25–57.17)	43.71 (19.04)	2 (0.42–75.38)	37.90 (53.00)	41.40
Wax	1 (na)	13.67 (na)	2 (0.50–14.00)	7.25 (9.55)	11.12
Timber	3 (27.16–72.97)	44.85 (24.62)	1 (na)	10.67 (na)	31.24
Thatching materials	1 (na)	17.73 (na)	1 (na)	6.00 (na)	13.06
Fuelwood	4 (0.52–86.29)	22.18 (42.74)	3 (0.18–41.71)	15.82 (22.58)	19.65
Fodder	2 (26.07–28.04)	27.06 (1.39)	1 (na)	17.88 (na)	23.40
Medicine	1 (na)	61.67 (na)	1 (na)	47.67 (na)	56.09
Other miscellaneous products	1 (na)	1.04 (na)	1 (na)	0.42 (na)	0.79
Total		**945.54**		**362.48**	**713.30**
Regulating and maintenance					
Carbon sequestration	2 (1.94–2.09)	2.02 (0.11)	1 (na)	1.80 (na)	1.93
Storm and surges protection	6 (14.04–705.29)	239.55 (248.55)	3 (17.54–1869.09)	740.10 (990.43)	438.92
Soil erosion control	2 (2.09–2.16)	2.13 (0.05)	1 (na)	39.48 (na)	17.00
Waste assimilation	1 (na)	316.67 (na)	2 (93.20–500.05)	296.63 (287.69)	308.69
Gas regulation	1 (na)	51.67 (na)	2 (6.86–65.79)	36.33 (41.67)	45.56
Other coastal protection	1 (na)	254.49 (na)	1 (na)	233.33 (na)	246.06
Nursery and habitat services	3 (9.71–805.05)	339.53 (415.00)	1 (na)	332.14 (na)	336.59
Biodiversity conservation	2 (652.58–847.95)	750.27 (138.15)	1 (na)	131.58 (na)	503.84
Pollination	1 (na)	33.33 (na)	1 (na)	17.34 (na)	26.96
Pest and disease control	1 (na)	11.67 (na)	1 (na)	6.45 (na)	9.59
Gene pool conservation	2 (644.57–1269.18)	956.88 (441.67)	1 (na)	184.67 (na)	649.31

Table 2. *Cont.*

ES	Bangladesh Sundarbans		Indian Sundarbans		Entire Sundarbans
	No. Observation (Range)	**Mean (±SD)**	**No. Observation (Range)**	**Mean (±SD)**	
Total		**2958.21**		**2019.85**	**2584.46**
Cultural					
Recreation and tourism	6 (1.77–360.91)	129.74 (142.59)	3 (2.51–526.65)	184.65 (307.36)	161.36
Aesthetic value and inspiration for culture (landscape, flora, and fauna)	2 (0.01–0.50)	0.26 (0.35)	1 (na)	0.28 (na)	0.27
Total		**130.00**		**184.93**	**151.88**

na = not available. Economic value of ES for entire Sundarbans = (mean value of Bangladesh Sundarbans ES × total area of Bangladesh Sundarbans) + (mean value of Indian Sundarbans ES × total area of Indian Sundarbans)/total area of entire Sundarbans. For instance, Fish = (418.92 × 601,700) + (107.99 × 398,300)/1,000,000 = 295.08.

Table 3. Estimated livelihood values of Sundarbans ES (US \$ collector^{-1} yr^{-1}).

ES	Bangladesh Sundarbans (SIZ)		Indian Sundarbans (SBR)		Entire Sundarbans
	No. Observation (Range)	**Mean (±SD)**	**No. Observation (Range)**	**Mean (±SD)**	
Fish	8 (259.62–1376.10)	920.70 (438.17)	2 (457.96–583.41)	520.69 (88.71)	720.70
Shrimp	3 (259.62–1366.72)	893.06 (570.58)	1 (na)	450.00 (na)	671.53
Shrimp fry	4 (259.62–2216.07)	1063.44 (955.23)	1 (na)	675.50 (na)	869.47
Crab	8 (48.07–2437.99)	876.42 (914.50)	1 (na)	134.15 (na)	505.29
Honey	6 (111.64–1279.30)	446.81 (428.03)	1 (na)	80.91 (na)	263.86
Wax	1 (na)	20.67 (na)	1 (na)	14.16 (na)	17.42
Thatching materials	8 (61.24–1316.47)	676.26 (526.93)	1 (na)	333.33 (na)	504.80
Fuelwood	5 (26.07–589.22)	195.09 (240.33)	1 (na)	110.00 (na)	152.55
Fodder	1 (na)	16.00 (na)	1 (na)	9.33 (na)	12.67
Other miscellaneous products	1 (na)	6.45 (na)	1 (na)	4.67 (na)	5.56

na = not available. Livelihood value of ES for entire Sundarbans = (ES value of Bangladesh part + ES value of Indian part)/2. For instance, Honey = (446.81 + 80.91)/2 = 263.86 (average of mean value of Bangladesh and Indian Sundarbans).

4.2.1. Provisioning Ecosystem Services

Among the provisioning ES, the highest value was found for fish, and the total estimated economic value for the whole Sundarbans is US \$ 295.08 ha^{-1} yr^{-1}. The value for Bangladesh (US \$ 418.92 ha^{-1} yr^{-1}) is about four times higher compared to the one for India (US \$ 107.99 ha^{-1} yr^{-1}). The estimated values for shrimp and shrimp fry for the whole Sundarbans are US \$ 80.12 ha^{-1} yr^{-1} and US \$ 57.75 ha^{-1} yr^{-1}, respectively. Values found for the Bangladesh Sundarbans are about three times higher than those for the Indian part of the area. It was found that crabs rank second (after fish) in terms of contribution to the total value of provisioning ES: their economic value for the whole Sundarbans was US \$ 83.61 ha^{-1} yr^{-1}. The estimated economic values of honey and wax for the whole Sundarbans are US \$ 41.40 ha^{-1} yr^{-1} and US \$ 11.12 ha^{-1} yr^{-1}, respectively. The economic value of crab and wax for the Bangladesh Sundarbans is found to be two times higher than for the Indian Sundarbans, while values found for honey are very similar for the countries (Table 2).

Timber and thatching materials were estimated to have a value of US \$ 31.24 ha^{-1} yr^{-1} and US \$ 13.06 ha^{-1} yr^{-1}, respectively, for the whole Sundarbans. As for many other provisioning ES, the value of these ES is also higher in studies referring to the Bangladesh part of the Sundarbans compared to those covering the Indian one. The estimated economic values for fuelwood and fodder for the Sundarbans are US \$ 19.65 ha^{-1} yr^{-1} and US \$ 23.40 ha^{-1} $yr^{-1,}$ respectively. The values of these two ES are about one and a half times higher for the Bangladesh Sundarbans than the Indian part. The economic value of medicine and other miscellaneous products are US \$ 56.09 ha^{-1} yr^{-1} and US \$ 0.79 ha^{-1} yr^{-1}, respectively, with values reported for Bangladesh being higher than those reported for India (Table 2).

4.2.2. Regulating and Maintenance Ecosystem Services

The estimated regulating and maintenance of ES for the Sundarbans include protection against storms and surges, biodiversity conservation, gene pool conservation, nursery and habitat services, waste assimilation, gas regulating, soil erosion control, pollination, pest and disease control, carbon sequestration, and other coastal protection ES (Table 2). The highest and lowest economic values for the whole Sundarbans were found for gene pool conservation (US \$ 649.31 ha^{-1} yr^{-1}) and carbon sequestration (US \$ 1.93 ha^{-1} yr^{-1}), respectively (Figure 5). Except for storm and surges protection and soil erosion control, the values of all other ES were higher for the Bangladesh Sundarbans than for the Indian ones. The largest value gaps between the two countries were found for biodiversity and gene pool conservation, which show values about five times higher for the Bangladesh Sundarbans than for the Indian ones. However, the values for storm and surges protection were three times higher for the Indian Sundarbans (Figure 5).

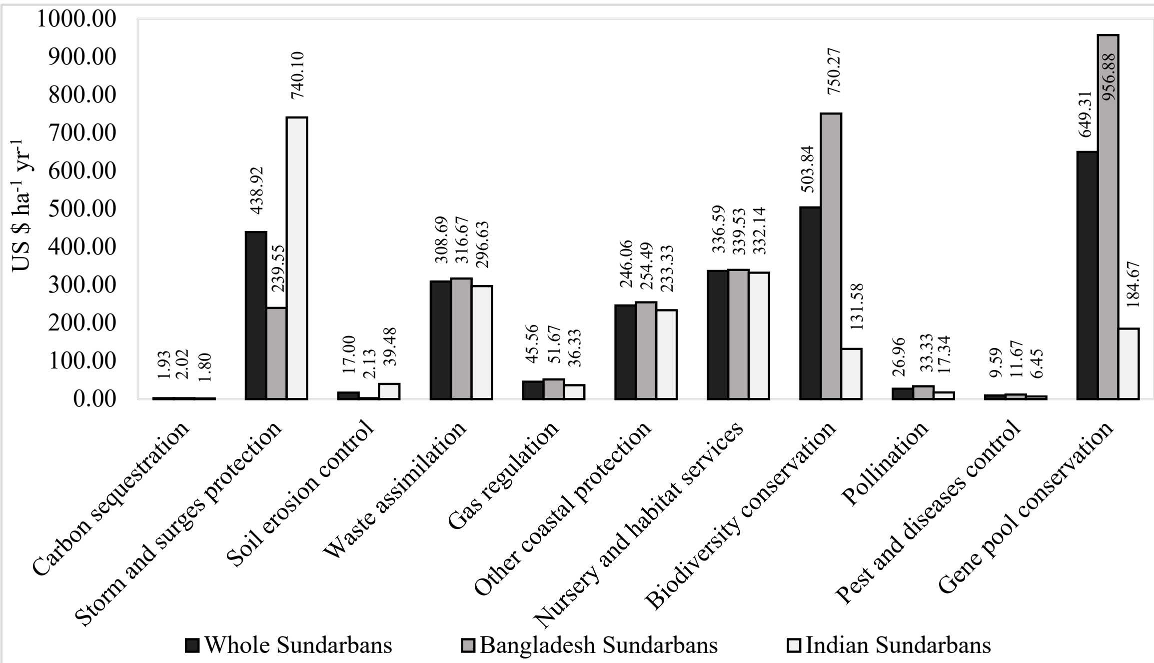

Figure 5. Estimated economic values of regulating and maintenance services of Sundarbans.

4.2.3. Cultural Ecosystem Services

The estimated economic value for recreation and tourism services for the whole Sundarbans is US \$ 151.88 ha^{-1} yr^{-1}, being higher for the Indian Sundarbans (US \$ 184.65 ha^{-1} yr^{-1}) than for Bangladesh ones (US \$ 130.00 ha^{-1} yr^{-1}). We also estimated the aesthetic value and inspiration for the culture (landscape, flora, and fauna) of the Sundarbans, which is almost the same for the Bangladesh and Indian Sundarbans (Table 2).

4.3. Livelihood Values of Sundarbans Provisioning Ecosystem Services

Among the estimated average livelihood values, the highest annual income value for each collector with reference to the whole Sundarbans was found for shrimp fry (US $ 869.47 collector^{-1} yr^{-1}) and fish (US $ 720.70 collector^{-1} yr^{-1}). The annual income values of each fish, shrimp, and shrimp fry collector in the Bangladesh Sundarbans were found to be almost double compared to Indian ones. The largest income value gap was found for crabs, where the annual income for each collector was US $ 876.42 collector^{-1} yr^{-1} in the Bangladesh Sundarbans and US $ 134.15 collector^{-1} yr^{-1} in Indian ones. The estimated average livelihood value for the honey of the whole Sundarbans is US $ 263.86 collector^{-1} yr^{-1}: the annual income for each collector in the Bangladesh Sundarbans is five and a half times higher (US $ 446.81 collector^{-1} yr^{-1}) compared to the Indian Sundarbans (US $ 80.91 collector^{-1} yr^{-1}). Among other ES services, thatching materials, fuelwood, fodder, and other miscellaneous products were estimated to have a significant livelihood value for the entire Sundarbans, and the annual income values for each collector from these ES are much higher in the Bangladesh Sundarbans than Indian ones (Table 3).

4.4. Meta-Regression Model of Economic and Livelihood Values

The meta-regression results for Model 1 (single variable effect) indicate that the regulating and maintenance of ES have a positive and significant effect on economic values; however, cultural services show a negative value (Table 4). This reflects the fact that the regulating and maintenance of ES tends to show higher estimated values than the cultural ES. In terms of valuation methods used, benefit transfer and travel cost methods had positive effects, but the contingent valuation method had negative effects. The benefit transfer method produced much higher economic estimates than the travel cost method. However, Model 2 (all variables effect) and Model 3 (two variables effect: ES types and valuation methods) showed that the travel cost methods produced higher economic estimates and were more statistically significant than the benefit transfer method. In Model 1, the study site showed a negative effect, whereas in Model 2, it showed a positive effect. For both Model 1 and Model 2, we found that GDP per capita had positive and significant effects on economic values; however, population density had a negative value (Table 4).

Table 4. Meta-regression results of economic values with individual and combined effects. The omitted variables of the meta-regression models are provisioning services in the ES types, market price in the valuation method types, Bangladesh Sundarbans (6000 km^2) in study area category, GDP/capita > US $ 1500 in GDP/capita category, and Population density/km^2 > 1000 in density/km^2 category.

Variables		Model 1	Model 2	Model 3
		Coefficients (SD)	Coefficients (SD)	Coefficients (SD)
	Constant	3.37 *** (0.36)	3.22 *** (0.40)	2.96 *** (0.33)
Types of ES	Regulating and maintenance	1.32 * (0.52)	−1.72 (1.13)	−1.38 (1.14)
	Cultural	−0.95 (0.73)	−6.64 *** (1.40)	−6.60 *** (1.45)
Valuation method	Benefit transfer	1.30 * (0.53)	2.96 * (1.12)	2.83 * (1.14)
	Travel cost	0.25 (0.75)	6.18 *** (1.42)	6.41 *** (1.47)
	Contingent valuation	−2.69 * (1.19)	(na)	(na)
Study area	Study site	−0.58 (0.52)	1.57 (1.14)	
Socio-economic	GDP/capita	1.04 (0.57)	1.29 * (0.53)	
	Population density/km^2	−0.82 (0.50)	−2.43 * (1.14)	
	N = 89			
	Adjusted R^2	0.27	0.30	0.25

* Statistically significant at 10% level at 0.1, ** Statistically significant at 5% level at 0.05, *** Statistically significant at 1% level at 0.01. na = not available.

The meta-regression results for Model 1 and Model 2 showed that the coefficient of the study site was negative, but the coefficient of Model 1 is statistically significant on the livelihood values of ES (Table 5). In terms of socio-economic factors, the meta-regression results for the Model 1, Model 2, and Model 3 models showed that the GDP per capita has statistically significant positive effects on the livelihood values of ES, i.e., the estimated value of ES tends to be higher when the GDP is higher. On the contrary, population density had negative values but was statistically significant for Model 2. The adjusted R^2 values calculated for these three models were the same (Table 5).

Table 5. Meta-regression results of livelihood values with individual and combined effect. The omitted variables of the meta-regression models are Bangladesh Sundarbans (6000 km^2) in study area category, GDP/capita > US $ 1500 in GDP/capita category, and Population density/km^2 > 1000 in density/km^2 category.

Variables		Model 1	Model 2	Model 3
		Coefficients (SD)	**Coefficients (SD)**	**Coefficients (SD)**
	Constant	5.52 *** (0.31)	5.14 *** (40)	5.14 *** (40)
Study area	Study site	−1.16 * (0.51)	−0.56 (0.57)	− −
Socio-economic	GDP/capita	1.20 ** (40)	0.97 * (0.46)	0.97 * (0.46)
	Population density/km^2	−1.16 * (0.51)	(na)	−0.56 (0.57)
	N = 56			
	Adjusted R^2	0.13	0.13	0.13

* Statistically significant at 10% level at 0.1, ** Statistically significant at 5% level at 0.05, *** Statistically significant at 1% level at 0.01. na = not available.

5. Discussion

In this section, results are discussed vis-a-vis existing literature and comments.

5.1. Overview of Ecosystem Services Studies for Sundarbans

With reference to the Sundarbans, the results of our study revealed that the provisioning of ES was more studied than the regulating and maintenance of cultural services. The reason behind this result may be due to the existing gaps regarding identification, classification, and valuation techniques for ES, which are different from provisioning ones [13]. The literature gap between provisioning ES, regulating and maintenance, and cultural ones is likely to be even broader when considering that some of them (e.g., timber and fish) were not commonly referred to as ES until a few years ago. This reflects the fact that, unlike most of the provisioning ES, regulating and maintenance and cultural ES are normally not traded on the market. Therefore, they require specialized knowledge and dedicated studies to find out their economic values. Interest in the economic value of non-marketed ES has emerged in the last years, when new paradigms regarding the economics of ES, including accounting and their inclusion into market-based mechanisms, have been proposed [48]. All in all, studies about the economic value of ES were more common in the Bangladesh Sundarbans than in the Indian ones. The reason behind this may be that the Bangladesh Sundarbans alone constitute about half of the forest cover and the single largest source of ES in the country [50,51], which plays an important role in both productive and protective functions [42]. In addition to this, it is a world heritage site and the largest mangrove forest in the world, which conveys a role in terms of national identity for Bangladesh; therefore, the national government, as well as other national and international organizations, pay extra attention to conserve this area [30].

The literature covered by the review is highly diversified in methodological terms (e.g., different valuation methods, interest rates and currencies, different scales and spatial scopes, etc.), and this ultimately reflects on different values for the same ES from the same forest and year. Moreover, just a few studies assess the impact of dependent, independent, and multiple variables on the estimations via statistical models (e.g., regression models).

The livelihood values estimated by existing literature are based on collectors' income from collectible and marketable products (provisioning ES). However, collectors' own consumption was not included in estimated livelihood values. Nonetheless, it represents a significant component of the total livelihood value and definitively contributes to livelihood security. Moreover, percentages of collectors for the same ES in the same area reported by existing literature are not consistent and vary significantly [15,26]. Since this did not allow us to calculate the average livelihood value for the whole Sundarbans as a weighted average (weighted average livelihood value of the Sundarbans ES (US $ collector^{-1} yr^{-1}) = (ES value of Bangladesh Sundarbans × number of collector in Bangladesh Sundarbans + ES value of Indian Sundarbans × number of collector in Indian Sundarbans)/(number of collector in Bangladesh Sundarbans + number of collector in Indian Sundarbans)), we used a simple average.

Existing literature mainly addressed direct and indirect use values, while option or non-use values remain largely uncovered. Therefore, the total economic value for the Sundarbans is still far from being fully captured, and a relevant research and knowledge gap exists. This may finally reflect on management and conservation strategies since Iqbal [52] reported that the economic valuation of non-use values is significant for reducing and hampering the ES of the Sundarbans.

5.2. Economic Values of Sundarbans Ecosystem Services

Economic values estimated for the Sundarbans ES are discussed below.

5.2.1. Provisioning Ecosystem Services

Provisioning ES delivers important economic and livelihood values. Our study revealed that the economic value of aquatic resources (fish, shrimp, shrimp fry, and crab) was much higher for the Bangladesh Sundarbans than for the Indian ones. This may be due to the fact that the Bangladesh part of the Sundarbans is composed of many rivers and canals [26,50] characterized by the high availability of many valuable aquatic resources like hilsa (*Tenualosa ilisha*) fish. The importance of water-based provisioning services provided by mangrove forests is confirmed by other studies in the same region. For example, Gunawardena and Rowan [53] reported fish values for mangrove forests in Southern Sri Lanka to be US $ 451 ha^{-1} yr^{-1}, i.e., higher than estimated values for the Indian (US $ 107.99 ha^{-1} yr^{-1}) and whole Sundarbans (US $ 295.08 ha^{-1} yr^{-1}), but not much higher compared to the Bangladesh Sundarbans (US $ 418.92 ha^{-1} yr^{-1}). According to Bann [54], the fish value for Cambodian mangroves was US $ 84 ha^{-1} yr^{-1} in 1996 constant price, equal to 2019 US $ 137.58 ha^{-1} yr^{-1} (using inflation rate); this value is much lower than estimations for the Sundarbans.

The estimated economic values for honey and wax were higher for the Bangladesh Sundarbans: this may be due to the high density of forests, availability of important pollen and nectar-producing plants (i.e., *Aegicerus corniculatum*, *Ceriops decandra*, *Avicennia officinalis*, *Sonneratia apetala*, *Excoecaria agallocha*, and *Xylocarpus mekongensis*) and honeybees species (i.e., *Apis dorsata*) [8]. Quader et al. [9] reported that the Bangladesh Sundarbans was categorized by a higher proportion of dense, moderately dense, and a lower proportion of sparse mangroves compared to the Indian ones. We also found that the economic values of timber and thatching materials were higher for the Bangladesh Sundarbans than Indian ones: one possible explanation for this is that the most valuable plant species like Sundori (*Heritiera fomes*) and golpata (*Nypa fruticans*) grow more in the Bangladesh Sundarbans [26,55,56]. As for other studies on mangrove forests, Gunawardena and Rowan [53] reported timber values for Southern Sri Lankan mangrove forests (US $ 40 ha^{-1} yr^{-1}) that are higher than estimated values for Indian (US $ 10.67 ha^{-1} yr^{-1}) and the whole Sundarbans (US $ 31.24 ha^{-1} yr^{-1}), but not very different from those found for the Bangladesh Sundarbans (US $ 44.85 ha^{-1} yr^{-1}). The IUCN [57] reported fuelwood value for natural mangroves in Sri Lanka to be US $ 1 ha^{-1} yr^{-1}, i.e., about 5% of the value estimated for the Sundarbans. The UNEP [58] reported that the fuelwood value for Kenyan mangroves was

US $ 16.8 ha^{-1} yr^{-1} in 2011 constant price, equivalent to 2019 US $ 19.14 ha^{-1} yr^{-1}, which is of the same magnitude of estimated values for the Sundarbans.

The whole Sundarbans support the provision of a lot of medicinal plants, but our study found that the value of medicinal plants for the Bangladesh Sundarbans is higher than the value for the Indian part. One possible reason is the presence of important species in Bangladesh; for example, the young branches of *Heriteria fomes* are used for treating gastrointestinal disorders, skin diseases, and diabetes [59], and newly developed *Nypa fruticans* shoots are used as a vermicide [60].

5.2.2. Regulating and Maintenance Ecosystem Services

Our results showed that values of the regulating and maintenance of ES tend to be higher for the Bangladesh Sundarbans compared to Indian ones. However, available values for ES, like storm and surges protection and soil erosion control values, make an exception. Possible reasons behind this could be that most of the tropical storm paths were over the Bangladesh Sundarbans, and therefore, damages by these disasters were higher in Bangladesh than in India [9,61,62]. When comparing with other studies about mangrove forests, UNEP [58] reported that the storm protection value for Kenyan mangroves was US $ 95 ha^{-1} yr^{-1} in 2015 constant price, equivalent to 2019 US $ 102.47 ha^{-1} yr^{-1}; this is lower than the value estimated for Bangladesh (US $ 239.55 ha^{-1} yr^{-1}), Indian (US $ 740.10 ha^{-1} yr^{-1}) and whole Sundarbans (US $ 438.92 ha^{-1} yr^{-1}).

The carbon sequestration values were higher for the Bangladesh Sundarbans: this may be due to the presence of high carbon content trees and their density. For instance, Rahman et al. [10] reported that *Heritiera fomes* dominated forest types and stored more ecosystem carbon than other vegetation types. In the case of the Bangladesh Sundarbans, *Heritiera fomes* constitutes 17% of the total forest cover [56], while no pure *Heritiera fomes* stand occurs on the Indian site, as this species only occurs in mixed stands with other species (*Ceriops decandra* and *Excoecaria agallocha*), totaling only 0.32% of the total cover [26]. Waste assimilation and gas regulating depend on the conditions of plant anatomical structure, density, physiology, and other abiotic factors (i.e., sunlight, water, soil) [63]. Dasgupta et al. [64] reported that *Heritiera fomes* show a higher photosynthesis rate than other mangrove species. In addition to this, Edu et al. [65] reported that mangrove ecosystems serve as sinks for the deposition of waste from anthropogenic sources such as domestic, industrial, and agricultural discharges, and the same study also examined that *Nypa fruticans* absorbs significant amounts of heavy metals (i.e., Zn, Mn, Cr, and Fe) along with other mangrove species. The density of stands, including the two abovementioned species, tends to be higher in the Bangladesh Sundarbans [55,56]; this could be the reason for the higher economic values of waste assimilation and gas regulating of ES reported for the Bangladesh Sundarbans compared to the Indian part.

The estimated values of biodiversity conservation, gene pool conservation, nursery and habitat services, pollination, and pest and disease control for the Bangladesh Sundarbans were higher than those estimated for the Indian part. This difference is due to reported higher biodiversity in the Bangladesh Sundarbans, for example, in terms of the number of valuable species [7]. For instance, according to the 2015 tiger census in Bangladesh and the 2011 tiger census in India, about 180 tigers were estimated to be dwelling in the Sundarbans (106 in Bangladesh and 74 in India) [7]. Moreover, the Bangladesh Sundarbans support extensive fishery by providing habitat and protection for fish breeding and nursery for fish and shellfish [66].

5.2.3. Cultural Ecosystem Services

The scenic beauty, river cruising, fishing, bird watching, jungle trails, and wildlife watching in the Sundarbans attract many national and international tourists every year [67,68]. Nishat et al. [26] reported that the number of tourists and associated revenues for the Bangladesh and Indian Sundarbans has increased over the last few years. However, the reported number of international tourists for the Bangladesh Sundarbans is lower compared to

Indian ones. This could help explain the lower economic values for recreation and tourism ES for the Bangladesh Sundarbans. On the other hand, it is important to report that the art value provided by other forest zones of Bangladesh is far less compared to the Bangladesh Sundarbans [30]. For instance, the Bengal Tiger is considered the symbol of spirit and is also used in the logo of the Bangladesh Cricket Board (BCB) (BCB is the governing body of cricket in Bangladesh. Cricket is a sport that is now played throughout the world, and the most popular sport in Bangladesh). Moreover, the men's and women's cricket teams of Bangladesh are named the Tigers and the Tigresses. The Hindu religious community of Bangladesh and India also uses the replica of the Bengal Tiger to make statues in the Durga Puja (Durga Puja is an annual festival of the Hindu religion. During the puja, the sculpture-idols (locally called Pratima or Murti) are made, and Hindu people use them to pray based on their spiritual beliefs).

5.3. Livelihood Values of Sundarbans Provisioning Ecosystem Services

The findings of the study revealed that aquatic resources (i.e., fish, shrimp, shrimp fry, and crab) provided by the Sundarbans have significant livelihood values. However, income from the aquatic resources of Bangladeshi collectors is higher than that of Indian collectors (Table 3). Moreover, the number of collectors in the Bangladesh Sundarbans area is higher than in the Indian part. For instance, Islam [23] reported that 0.3 million collectors caught fish and 0.9 million people worked as fish labour (i.e., loading, unloading, packaging) within the SIZ of Bangladesh. According to Haq [69], about 0.2 million Bangladeshi fishers operate daily in this area for their livelihood security. Nishat et al. [26] reported that 0.15 million people engaged in fish collection within the SBR of India. Shrimp, shrimp fry, and crab are important sources of income, and women and young children are mostly involved in the collection of these arthropods. Islam [23] reported that 0.19 million and 0.4 million people in the Bangladesh SIZ area collect shrimp and shrimp fry, respectively. Nishat et al. [26] reported that 0.15 million people in the India SBR area collect shrimp and shrimp fry. According to Islam [23], there are 0.075 million crab collectors in the SIZ of Bangladesh.

Among other livelihood values, collectors' income from honey and wax was estimated to have a higher value for the Bangladesh Sundarbans than for Indian ones. Based on existing literature, this seems to depend (among other factors) on the different numbers of collectors in the two countries. Islam [23] reported that 0.025 million people engaged in honey collection in the Bangladesh Sundarbans, while Ghosh et al. [7] reported that 0.002 million collectors collect honey from the Indian Sundarbans. The main thatching material from the region is represented by the *Nypa* leaf, which is used mainly for housing, boat roofing, fence-making, and fuel [7]. Differences in *Nypa* collection conditions and protection regimes in Bangladesh and India contribute to explaining different livelihood values for this ES. Islam et al. [55] reported that the livelihoods of *Nypa* leaf collectors indirectly affect the total household income in the SIZ of Bangladesh. Our study found that the income and number of collectors were higher for the SIZ in Bangladesh than for the SBR in India. Islam [23] reported that 0.079 million people living within the SIZ collected thatching material from the Bangladesh Sundarbans. For better protection, the collection of *Nypa* leaf from the Indian Sundarbans has been stopped by the government since 1978 [70].

Apart from these services, fodder and other miscellaneous products contribute to uplifting the socio-economic condition of poor communities around the Sundarbans. For instance, the fruit of Nypa is used traditionally to prepare sugar and wine [55]. We found that income for collectors from these products was higher in Bangladesh than in India. Nishat et al. [26] reported that 32,000 households are involved (at least one member per household) in collecting NTFP—like honey, thatching materials, fuelwood, fodder, and other miscellaneous products—in the Indian Sundarbans: this means that at least about 0.032 million collectors are directly engaged in the collection of these products.

5.4. Factors Influencing Economic and Livelihood Value Estimates of Ecosystem Services

The meta-regression results show how estimates of ES vary with explanatory variables. For instance, ES are not independent from one another [71]. Similarly, the positive and negative values of the same ES (i.e., regulating and maintaining services) in our meta-regression models were varied due to the effect of other explanatory variables. The positive and significant effect of regulating and maintenance services in model Model 1 indicates the higher estimates of ES in the study. Hence, more studies and higher estimates might be the reason for cyclonic storms and their impact on biodiversity and coastal people. Neogi et al. [37] reported that the incidence of cyclonic storms has increased in the last century, and the results of our meta-analysis showed that the study on regulating and maintenance services has increased in the last decades (Figure 2). However, the negative values of cultural services indicate lower estimates compared to regulating and maintenance services. In Model 2 and Model 3, the coefficients of cultural services are negative and statistically significant, indicating the influence on estimated economic values of ES. According to Chakraborty et al. [67], the tourism facilities are not good enough for the Sundarbans, and the people of this area cannot fully realize the value of recreational services. Therefore, it is difficult to judge, express, and understand economic values for estimation. In addition to this, most of the recreational service studies are on designated areas such as national parks or attractive touristic places [72,73], which indicates the lower estimates of recreational and tourism services of the Sundarbans like other mangrove forests.

The value of the same ES can also vary according to the methodology used for the estimation [47]. In Model 1, we found positive coefficients for the benefit transfer and travel cost method, but the value for the benefit transfer method was much higher and statistically significant, which indicates higher economic estimates of ES. On the other hand, Model 2 and Model 3 showed that the travel cost methods produced higher economic estimates than the benefit transfer method. However, the benefit transfer method is susceptible to errors resulting from a lack of correspondence between the original site and the study site in terms of ecological, socio-economic, and other environmental factors [74,75], which would have adverse consequences for policy decisions [76].

We found that the coefficient of the study area is negative for Model 1 but positive for Model 2, where we used a combination of all variables. The positive coefficient indicates that the ES value per hectare of the valued site tends to increase when the mangrove area increases [77]. Similarly, our meta results showed that the ES value per hectare is higher in larger mangrove sites (the Bangladesh Sundarbans) than in smaller ones (the Indian Sundarbans). The meta-regression Model 1 and Model 2 showed a positive and significant effect of per capita GDP on estimated economic and livelihood values. However, population density had a negative value. The positive and significant effect of per capita GDP on the estimated economic value of ES matches the results of Brander et al. [77] and Salem and Mercer [78]. This positive impact of per capita GDP demonstrates that the Sundarbans ES have higher values with higher incomes of Bangladeshi and Indian people.

5.5. Research Challenge and Opportunity to Support Decision Making

In the last decades, the scientific and political communities have been increasingly concerned about biodiversity conservation, and the focus of this has been shifting from intrinsic to instrumental values [47,79]. Therefore, economic valuation studies have become among the most used approaches in the field of ES science [80]. Since the estimation of monetary values that reflect the societal importance of ES is seen as a prerequisite for better management decisions [81] and considering that acknowledging the importance of ES valuation is increasing at the policy level [30], the results of this study might be useful for policymakers to inform and improve suitable conservation strategies for the Sundarbans.

This includes the following:

- Our findings might contribute to advancing the valuation and decision-making process regarding NTFP collection as well as the management of other provisioning ES. For example, information on the value of fuelwood collected might help design projects to supply alternative sources of energy (i.e., natural gas, biogas, and electric stoves). Similarly, information on the value of honey and thatching materials collected in the area may help identify alternative/complementary sources of income (e.g., poultry farming) to avoid/reduce extensive extraction and biodiversity conservation.

- Reliable economic estimates of ES can also inspire management practices aimed at resource conservation and responsible management, as well as represent key information for defining proper market-based mechanisms [82] to remunerating ES without an explicit market.
- Economic valuation of ES is also helpful in understanding the potential of an area with regard to the development of development opportunities to support local economies. This could be, for example, the case of cultural ES and, in particular, of tourism and recreation activities that, if properly valued, might create opportunities for the protection and sustainable use of ecosystems, including coastal ones like mangrove forests in the Sundarbans [67].
- Environmental risks and resources affect the migration and mobility of people. However, non-economic services are important for creating habitation in a place [83]. The Sundarbans support millions of people by providing protection against storms and surges, along with provisioning ES, but people are not aware of the protection services [21,61,84,85]. Getting the value of storm and surges protection of the Sundarbans might be helpful for advance thinking of alternative solutions (i.e., coastal plantations, cyclone-resistant buildings, cyclone-safe centers, etc.) to protect settlements and reduce migration of people due to these disasters.

6. Conclusions

The Sundarbans provide a wide range of ES and support to the livelihood of millions of people in the coastal areas of both Bangladesh and India. However, studies on the estimation of ES originating from these areas are still very limited. Our research indicates that the number of economic and livelihood valuation studies increased gradually. However, most of the available studies focus on provisioning ES while regulating and maintenance, and cultural ES, are less addressed. The number of studies and ES values are distributed unevenly between the Bangladesh and Indian Sundarbans; they tend to be higher for the former with respect to the latter, although cultural ES, with reference to the value of recreation and tourism, make an exception. The estimated livelihood values indicate that the annual income of each collector in Bangladesh is higher compared to the income estimated for collectors in India. Our meta-regression model identifies that the estimated economic and livelihood values are influenced by the type of ES, valuation methods, study area, and other socio-economic factors (e.g., GDP per capita and population density).

The degradation and deforestation of the Sundarbans are mainly due to anthropogenic causes (i.e., over-exploitation of resources, agricultural expansion, and industrialization). Moreover, the number of forest-dependent people is still increasing in the Sundarbans areas, which may lead to a growing demand for resources. Therefore, the findings of our paper might be helpful in the decision-making for sustainable resource management and allocation by strategy planners and resource managers. Moreover, the local people can become aware of the economic and livelihood values of ES by making hidden values visible. Most importantly, the findings of our study might contribute to drawing the attention of policymakers, researchers, investors, and people in general to invest their knowledge and funds in further research on ES valuation. By getting a clear figure of the value of the Sundarbans in terms of ES development projects, they can be better assessed and their implications fully considered.

The findings of this study are based on an extensive literature review and have a couple of limitations; these shall be considered for improving future research in this field. First, we estimated economic and livelihood values that did not cover all the ES derived from the Sundarbans; thus, we have not considered the huge number of ES forests provided to society. This is also linked to the fact that the review did not cover possible studies and valuations of ES available in local languages. Secondly, option or non-use values were not included in this study. Therefore, further research is required in the future to include all types of ES and to find out the total economic value of the Sundarbans. Moreover, the actual number of collectors for provisioning ES in the Bangladesh and Indian Sundarbans is still unclear because different studies have reported different figures. Knowing the actual number of collectors and their income from specific ES might be helpful in finding out the rate of dependency, which could support policy decisions by supporting the development of alternative sources of income to control extensive resource extraction from the forest.

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Data Availability Statement: The original contributions presented in the study are included in the article (Appendices A–C), further inquiries can be directed to the corresponding author/s.

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Conflicts of Interest: The authors declare that there are no conflicts of interest in publishing this paper.

Appendix A. Literature Searching and Screening Procedure

Step	Activities
1	Initially we searched for "Ecosystem services in Bangladesh" on Scopus until the end of 2023. The search focused on the title, abstract and key words. We found a total of 302 studies.
2	Our study focused on forest-based ecosystem services. Therefore, in the second step, we reduced the number of studies from the result step-1 (302studies) by using "Forest". In this search we got 201 papers that studied forest-based ecosystem services.
3	Then, we screened the number of studies from the result step-2 (201 studies) by using "Sundarbans". In this step we found 98 studies on Bangladesh Sundarbans.
4	Finally, we read the abstract and scanned all these studies (98 studies) to find out the papers on economic and livelihood valuation. However, 9 studies were found, that estimated economic and livelihood valuation on Bangladesh Sundarbans.
5	We also used other specific key-words to avoid missing the studies on economic and livelihood valuation. The additional key-words include economic valuation, economic value, livelihood value, livelihood valuation, provisioning services, regulating services, maintaining services, cultural services, non-timber forest products, fish, fuelwood, timber, fodder, thatching materials, carbon storage and sequestration, recreation and tourism, mangrove forest services, coastal forest services.
6	We also applied same procedure to find out the studies for Indian Sundarbans. Just in the beginning we started searching in terms of "Ecosystem services in India" (1650 studies), then "Forest" (970 studies), after that "Sundarbans" (84 studies). We read the abstract and scanned all the studies (84 studies) to find out the papers on economic and livelihood valuation and found 3 studies. We also followed steps-5 to locate the studies on Indian Sundarbans. No new studies were found.
7	We followed above mention steps for Science Direct, CABI Direct, CABI Forest Science Database and Google Scholar. Moreover, we collected relevant information from the policy reports of FD, DOE, IUCN, FAO, WB. In this step, we found 10 and 4 additional studies for Bangladesh and Indian Sundarbans respectively.
8	After finishing above mention search, we found 19 and 7 targeted studies for Bangladesh and Indian Sundarbans respectively.

Appendix B. Retrieved Literature, Ecosystem Services (and Corresponding Unit), Types of Value and Valuation Methods Used

Reference Used	Reporting Year (Study Site)	Ecosystem Services (in Different Unit)	Types of Value	Method Used	Data Base (Expressed Values in Similar Way)
Nobi et al. (2021) [32]	2018 (BS [1])	Recreation and tourism (value/ha/yr)	EV [3]	TC [5]	US $ ha^{-1} yr^{-1}
Barua et al. (2020) [30]	2017 (BS)	Fish (value/ha/yr)	EV	MP [6]	US $ ha^{-1} yr^{-1}
		Crab (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Timber (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Thatching materials (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Honey (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fuelwood (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fodder (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Other non-wood NTFPs (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Avoided storm damage (value ha^{-1} yr^{-1})	EV	BT [7]	US $ ha^{-1} yr^{-1}
		Other coastal protection (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Carbon sequestration (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Soil erosion control (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Biodiversity conservation (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Gene pool conservation (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Nursery and habitat services (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Recreation and tourism (value/ha/yr)	EV	TC	US $ ha^{-1} yr^{-1}
Barua et al. (2020) [30]	2017 (BS)	Fish (income/collector/yr)	LV [4]	MPCP [9]	US $ $collector^{-1}$ yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Fuelwood (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Thatching materials (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Other miscellaneous products (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
Sarker et al. (2020) [86]	2007 (BS)	Avoided storm damage (value ha^{-1} yr^{-1})	EV	BT	US $ ha^{-1} yr^{-1}
Mehvar et al. (2019) [87]	2017 (BS)	Fish and marine species (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Timber (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fuelwood (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Recreation/tourism (value/ha/yr)	EV	TC	US $ ha^{-1} yr^{-1}
		Landscape, flora and fauna (art value) (value/ha/yr)	EV	CV [8]	US $ ha^{-1} yr^{-1}

Reference Used	Reporting Year (Study Site)	Ecosystem Services (in Different Unit)	Types of Value	Method Used	Data Base (Expressed Values in Similar Way)
Kibria et al. (2018) [18]	2018 (BS)	Crab (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Fish (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Shrimp fry (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Shrimp catching (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Fuelwood (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
Rahman et al. (2018) [88]	2015 (BS)	Fishing (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fuel (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Honey (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fodder (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Storm protection (value/ha/yr)	EV	CV	US $ ha^{-1} yr^{-1}
		Erosion control (value/ha/yr)	EV	CV	US $ ha^{-1} yr^{-1}
		Habitat for fish breeding and nursery (value/ha/yr)	EV	CV	US $ ha^{-1} yr^{-1}
Akber (2018) [89]	2015 (BS)	Avoided storm damage (value households^{-1} yr^{-1})	EV	BT	US $ ha^{-1} yr^{-1}
BFD (2016) [90]	2016 (BS)	Carbon sequestration (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
Golub and Golub (2016) [91]	2016 (BS)	Golpata/Grass (Shon) (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Fish (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Shrimp (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Shrimp fry (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Tourism and cultural services (value/ha/yr)	EV	TC	US $ ha^{-1} yr^{-1}
		Nursery service (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Gene pool conservation (value/ha/yr)	EV	BT	US $ ha^{-1} yr^{-1}
Abdullah et al. (2016) [92]	2010 (BS)	Shrimp (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Shrimp fry (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Fuel wood (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Golpata/Grass (Shon) (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Fish (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}
		Other forest products (income/collector/yr)	LV	MPCP	US $ collector^{-1} yr^{-1}

Reference Used	Reporting Year (Study Site)	Ecosystem Services (in Different Unit)	Types of Value	Method Used	Data Base (Expressed Values in Similar Way)
Uddin et al. (2013) [68]	2012 (BS)	Fish (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Fuel wood (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Golpata (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Avoided storm damage (value/ha/yr)	EV	BT	US \$ ha^{-1} yr^{-1}
Bashar (2015) [93]	2015 (BS)	Tourism and cultural services (value/ha/yr)	EV	TC	US \$ ha^{-1} yr^{-1}
Hussain (2014) [66]	2013 (BS)	Avoided storm damage (value/yr)	EV	BT	US \$ ha^{-1} yr^{-1}
Winrock International (2013) [94]	2013 (BS)	Avoided storm damage (value/yr)	EV	BT	US \$ ha^{-1} yr^{-1}
		Tourism and cultural services (value/yr)	EV	TC	US \$ ha^{-1} yr^{-1}
Getzner and Islam (2013) [95]	2011 (BS)	Fish (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Golpata/Grass (Shon) (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
Islam and Islam (2011) [96]	2010 (BS)	Fish (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Golpata/Grass (Shon) (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
Islam (2010) [23]	2010 (BS)	Fish (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Shrimp (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Shrimp fry (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Honey (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Golpata/Grass (Shon) (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
Shah and Datta (2010) [97]	2001 (BS)	Fuel wood (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Fish (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Golpata (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
		Others (honey, fish fry, etc) (income/collector/yr)	LV	MPCP	US \$ collector^{-1} yr^{-1}
Mitchell (1995) [98]	1995(BS)	Fish (value/ha/yr)	EV	MP	US \$ ha^{-1} yr^{-1}
		Timber (value/ha/yr)	EV	MP	US \$ ha^{-1} yr^{-1}
		Fuelwood (value/ha/yr)	EV	MP	US \$ ha^{-1} yr^{-1}

Reference Used	Reporting Year (Study Site)	Ecosystem Services (in Different Unit)	Types of Value	Method Used	Data Base (Expressed Values in Similar Way)
Sannigrahi et al. (2019) [99]	2017 (IS)	Gas regulation (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Waste assimilation (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Soil erosion control (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Biodiversity conservation (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Recreation and tourism (value/yr)	EV	TC	US $ ha^{-1} yr^{-1}
Verma et al. (2017) [31]	2014 (IS [2])	Fish (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Honey (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Other non-wood NTFPs (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Avoided storm damage (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Other coastal protection (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Carbon sequestration (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Soil erosion control (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Gene pool protection (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Pest and diseases control (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Nursery and habitat services (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Pollination (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Gas regulation (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Waste assimilation (value/yr)	EV	BT	US $ ha^{-1} yr^{-1}
		Recreation and tourism (value/yr)	EV	TC	US $ ha^{-1} yr^{-1}
Basu et al. (2018) [100]	2018 (IS)	Crab (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fuel wood (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Recreation and tourism (value/yr)	EV	TC	US $ ha^{-1} yr^{-1}
Singh et al. (2010) [70]	2004 (IS)	Honey (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Wax (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Shrimp fry (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Crab (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Fish (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
		Fuelwood (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Crab (value/yr)	EV	MP	US $ ha^{-1} yr^{-1}

Reference Used	Reporting Year (Study Site)	Ecosystem Services (in Different Unit)	Types of Value	Method Used	Data Base (Expressed Values in Similar Way)
Banerjee (2010) [101]	2009 (IS)	Recreation and tourism(value/ha/yr)	EV	TC	US $ ha^{-1} yr^{-1}
		Fodder(value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fuel wood(value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Fish(value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Medicinal value(value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Honey and wax (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
		Storms protections (value/ha/yr)	EV	MP	US $ ha^{-1} yr^{-1}
ICSF (2009) [102]	2009 (IS)	Fish (income/collector/yr)	LV	MPCP	US $ $collector^{-1}$ yr^{-1}
Das (2009) [103]	1999 (IS)	Avoided cyclonic storm damage (value/ha/yr)	EC	BT	US $ ha^{-1} yr^{-1}

1. BS = Bangladesh Sundarbans, 2. IS = Indian Sundarbans, 3. EV = Economic value, 4. LV = Livelihood value, 5. TC = Travel cost 6. MP = Market price, 7. BT = Benefit transfer, 8. CV= Contingent valuation and 9. MPCP = Market price of collected products.

Appendix C. Classification of Identified ES According to CICES

Section	Division	Group	Class	Placing of Identified ES
Provisioning	Biomass	Nutrition	Wild plants, algae and their outputs	Honey
			Wild animals and their products	Fish, shrimp, shrimp fry and crab
		Materials	Fibres and other materials from plants, algae and animals for direct use or processing	Wax, medicine
			Materials from plants, algae and animals for agricultural use	Timber, thatching materials and fodder
		Energy	Plant-based resources	Fuelwood
	Water	(Nutrition, materials and energy)	--	--
Regulating and maintenance	Transformation of biochemical or physical inputs to ecosystem	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals	Waste assimilation
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	Carbon sequestration
		Mediation of nuisances of anthropogenic origin	--	--
	Regulation of physical, chemical and biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates	Soil erosion control
			Storm protection	Storm and surges protection
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere	Gas regulation
		Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (including gene pool protection)	Nursery and habitat services, gene pool conservation and biodiversity conservation
			Pollination (or 'gamete' dispersal in a marine context)	Pollination
		Pest and disease control	Pest control (including invasive species)	Pest control
			Disease control	Disease control

Section	Division	Group	Class	Placing of Identified ES
Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage	Art value (landscape, flora and fauna)
			Characteristics of living systems that enable aesthetic experiences	Recreation and tourism
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	--	--	--

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